Arlindo Circulation: A Study of the Indonesian Sea's Circulation and Mixing. The Inverted Echo Sounder Component

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LONG TERM GOALS

The Arlindo Project ("Arlindo" is an acronym for Arus Lintas Indonen, meaning 'throughflow' in Bahasa Indonesia) is a joint oceanographic research endeavor of Indonesia and the United States. Arlindo has as its primary goal to study the circulation and water mass stratification within the Indonesian Seas in order to formulate a thorough description of the source, spreading patterns, inter-ocean transport and dominant mixing processes.

OBJECTIVES

The Indonesian Seas are important in terms of both local and larger scale ocean phenomena. The magnitude and variations of the Pacific to Indian Ocean throughflow is considered a key element in the thermohaline balance of the Indian and Pacific Oceans, and perhaps even to the global climate system. Indonesian oceanographic features may influence ENSO by governing the "seepage" of the western tropical Pacific warm pool water into the Indian Ocean. It provides an interactive link between the warm tropical water of these oceans. Furthermore advective and tidal induced mixing may govern to some extent the SST and sea-air coupling, with feedback on ENSO. The main objective of this work was to deploy an array of instruments to measure the throughflow across the Makassar Strait. The choice of the strait was based in previous results (Gordon and Fine, 1995) that proved that most of the throughflow from the Pacific to the India Ocean occurs through this strait. The main fieldwork consists of the deployment of current meter moorings, some of them equipped with temperature pods, inverted echo sounders, pressure gauges and hydrographic surveys including acoustic Doppler profiling and tracers. This Program was funded to carry out the inverted echo sounder (IES) component of Arlindo. As part of this grant, four inverted echo sounders equipped with pressure gauges (PIES) were deployed along the main axis of the Makassar strait bracketing the current meter mooring. The objective of these deployments is to measure the meridional throughflow by monitoring the pressure gradient along the strait, and to study internal waves and tides at the Makassar strait.

APPROACH

One of the parameters that will be measured with the PIES is the difference of pressure between sites. In a narrow channel in which the effects of rotation can be neglected, all of the flow is in the direction along the channel. The condition for the effects of rotation to be negligible is that the width of the

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channel is small compared to the Rossby Radius of deformation (R). Due to the proximity to the equator, the Coriolis parameter is almost zero and R is very large. Therefore, it can be assumed that all of the motion will be along the channel. The equations that govern this motion are basically the Bernoulli equation and the mass conservation equation. In first approximation, these equations can be solved for the total velocity, V, and a relation between the difference in pressure and the transport can be obtained. Indeed, all that can be measured with a PIES array is the pressure variability (these are free-fall deployed instruments and the depth at which they were deployed is unknown). In order to recall this pressure variability to velocity, all that is needed is a measurement of the current at one point. A current meter mooring will be deployed between the PIES and the mean current at the bottom will be used as the mean barotropic component. In addition, ADCP haul mounted measurements between the station will be obtained to provide another independent variable to calibrate the instruments. The second parameter measured with the IES is travel time, a quantity that is directly proportional to the integrated temperature and that can also be related to dynamic height.

WORK COMPLETED

Four inverted echo sounders equipped with pressure and temperature sensors (PIES) were deployed from the Indonesian research ship, *Baruna Jaya IV* during November 1996. ADCP measurements were collected along the PIES line twice on the way down for deployment and on the way back in a line 3 nm to the west, which passed through MAK-1. CTD stations were obtained at the site of deployments to calibrate the time series collected with the IES. The instruments were recovered during a cruise that took place in February 1998. Unfortunately, only three of the four PIES were recovered. Three time series of travel time, and three time series of bottom pressure and temperature are available for the analysis. During the recovery cruise, additional hydrographic data was collected, as well as direct measurements of the surface currents (ADCP). Up to date, the pressure and travel time series have been reduced. Figure 1 shows the three time series of travel time, bottom temperature and pressure collected with one of the instruments, PIES50. Figure 2 the corresponding

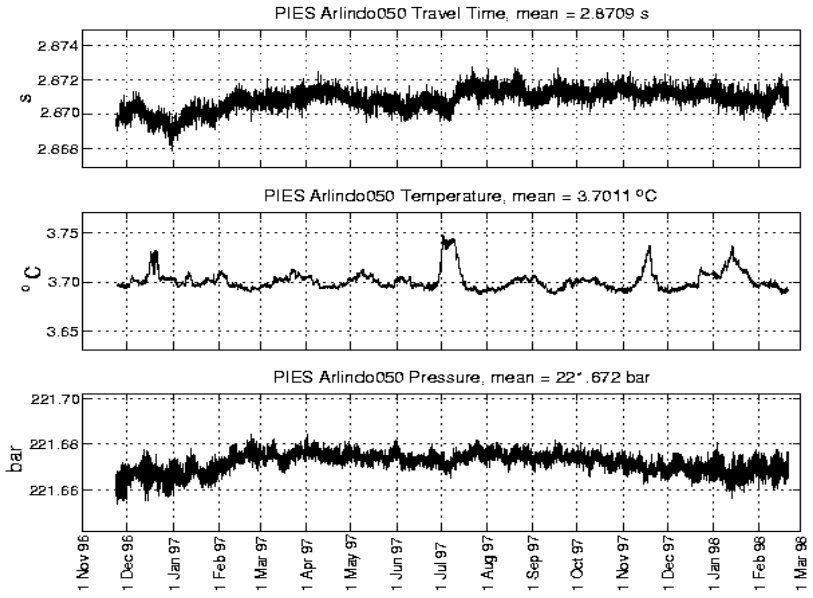

Figure 1

spectral analysis. Figure 3 is the difference in pressure between the instruments deployed at 1° 54'S 118° 18'E (PIES 62) and 2° 50'S 118° 27'E (PIES 50). Preliminary calculations using the Bernoulli equation for $\lambda = 2$, indicate that $\Delta P = \pm 1 \times 10^{-1}$ bars is equivalent to ± 10 Sv in transport.

IMPACT AND IMPLICATIONS

The moorings deployed during Arlindo (PIES and current meters) will be the first ones to be deployed in Indonesian waters. The data to be collected provide the first time series of the through flow across the Makassar strait, the major conduit for the exchange between the Pacific and Indian Oceans. This is a critical parameter to understand inter-ocean exchange. Inter-ocean transport within the Indonesian Seas is the primary means of exporting excess fresh water from the North Pacific Ocean. The efficiency of this transfer dictates to a large measure the meridional overturning of the Pacific and Indian Oceans and perhaps of the global thermohaline "conveyor belt." These processes are relevant to climate issues. In particular, to the El Niño phenomena as it allows a transfer of warm water in the eastern Pacific into the Indian Ocean, adjusting the volume of the warm pool.

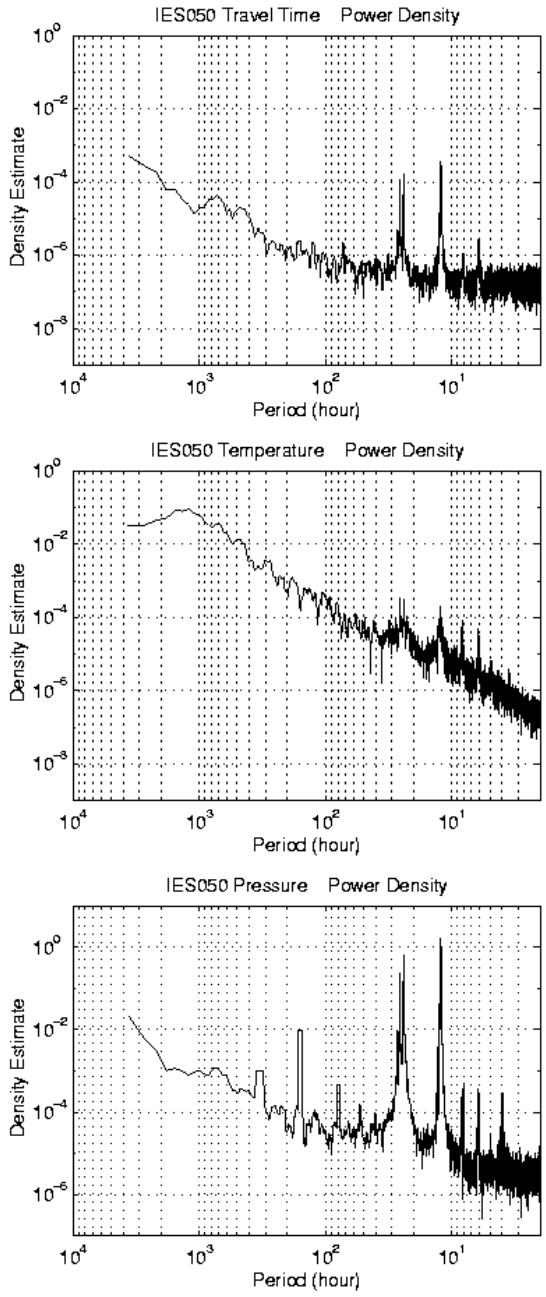

Figure 2

TRANSITIONS

As it was explained before, measuring the throughflow is of critical importance for the understanding of oceanic circulation and climate. A comparison between results obtained with the PIES and the CMM will be done in order to determine the optimal (cost/efficient) minimum array necessary to monitor the throughflow.

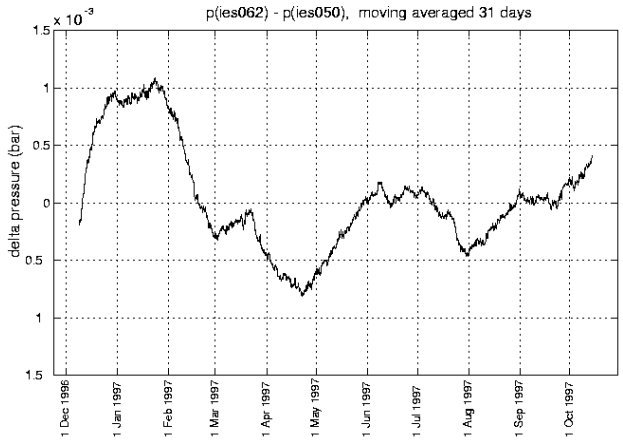

Figure 3

RELATED PROJECTS

This program is a component of the NSF and ONR funded Arlindo Circulation Program (Arnold Gordon, US Chief scientist). Components of Arlindo Circulation are: Current meter moorings (D. Pillsbury, PI) and Temperature pods (A. Ffield and S.L. Garzoli, co-PIs); PIES (S. L. Garzoli, PI); CTD oceanographic stations (A.L. Gordon, PI), and tracers (R. Fine, PI); shallow Pressure Gauges (N. Bray, PI); large scale remote sensing (C. Koblinski).

REFERENCES

The web address for Arlindo is:
http://www.ldeo.columbia.edu/physocean/proj_AM.html

Gordon, A.L. and R. Fine (1996) Pathways of water between the Pacific and Indian oceans in the Indonesian seas. Nature 379(6561): 146-149.